Рафикова Гульнара Рихситиллаевна
доцент, ТГТУ, Ташкент
Rafikova Gulnara Rikhsitillaevna, TSTU

ПОВЫШЕНИЕ ЭНЕРГОЭФФЕКТИВНОСТИ ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЙ ПУТЕМ ОПТИМИЗАЦИИ ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССОВ
IMPROVING ENERGY EFFICIENCY IN INDUSTRIAL ENTERPRISES THROUGH TECHNOLOGICAL PROCESS OPTIMIZATION

Аннотация: В статье рассматриваются вопросы повышения эффективности электропотребления с помощью управления технологическими процессами на промышленных предприятиях, а также оптимизация режимов электрических нагрузок энергоемких агрегатов, работающих в различных режимах. Предлагаются организационные мероприятия по снижению энергозатрат. Исследования, выполненные с использованием системного подхода, позволяют разработать методы оптимизации электрических нагрузок при определении чётких зависимостей между работой электропривода и их энергетическими показателями.

Abstract: The article addresses issues of enhancing electrical energy efficiency through the management of technological processes at industrial enterprises, as well as the optimization of electrical load modes for energy-intensive units operating in various modes. Organizational measures to reduce energy expenditures are proposed. Research conducted using a systems approach allows the development of methods for optimizing electrical loads by establishing clear relationships between the operation of electric drives and their energy indicators.

Ключевые слова: технологический процесс, режим работы, прерывный режим, непрерывный режим, оптимизация режимов, электропотребление, снижение энергозатрат, нормирование, энергоемкие потребители.

Keywords: technological process, operational mode, intermittent mode, continuous mode, mode optimization, electricity consumption, energy reduction, standardization, energy-intensive consumers.

Based on the results of conducted research and analysis of operational data on optimizing electricity consumption, the following tasks can be outlined to minimize energy costs across various industrial sectors [1,2]:

Optimization of Electricity Consumption Regimes:

a) Reducing energy costs in continuous and cyclic production processes of electrical power;

b) Minimizing energy consumption in direct and indirect action electrical units, covering high-temperature and low-temperature, as well as continuous and cyclic electrothermal processes;

c) Lowering energy costs during unstable operating modes, such as startup and shutdown phases;

d) Optimizing energy use in units operating under alternating modes of full power, reduced load, and idle states;

e) Tailoring power consumption strategies to the type of unit and the nature of load variations, whether linear or nonlinear.

Regulation of Electrical Loads to Mitigate "Peak" Demand [3,4]:

a) Reducing "peak" loads without additional capital investments or productivity losses;

b) Achieving the same results with capital investments but accepting reduced productivity;

c) Introducing cyclicity in technological processes to align pauses with peak load periods in the power system;

d) Establishing stable operational conditions for electrical load regulation systems.

Forecasting and Managing "Peak" Power Reduction:

a) Predicting the potential reduction in peak power demand (theoretical forecasts);

b) Estimating the time required to prevent a 30-minute exceedance of declared power during peak hours.

Technological Measures for Reducing Energy Costs:

a) Optimizing technological parameters in electrical power processes;

b) Implementing similar optimizations in electrothermal processes.

Minimizing Electricity Losses:

a) Reducing losses in the power supply system;

b) Lowering losses in electrical machines, devices, and electrothermal units;

c) Enhancing the efficiency of devices used for reactive power compensation.

Modernization of Machinery and Equipment:

a) Upgrading and modernizing the existing machinery and equipment to reduce energy costs effectively.

b) Replacement of machines, mechanisms, processes with less energy-intensive ones.

7. Implementation of organizational measures to reduce energy costs [5,6]:

a) Implementation of an automated system for accounting, monitoring, and managing the consumption of electricity, compressed air, water, gas, steam, etc.;

b) Organization of collection and storage of statistical information on the dynamics of energy indicators;

c) Development of standardization methods and organization of compliance monitoring.

Thus, the entire complex of research and implementation of energy-saving measures is reduced to solving 8 tasks, which in turn consist of 21 sub-tasks.

Optimization of electrical load modes of energy-intensive units operating in various modes.

Ensuring the minimum level of power consumption is one of the most important tasks when developing ESC and PEE technologies at industrial sites. It should be noted that the nature of power consumption is strictly governed by the technological regulations of the unit operating under both constant and variable load conditions. The complexity of solving this task is also due to the fact that in operating conditions there is a significant deviation of electrical loads due to random factors.

The use of a set of "standard charts" of electrical loads and their probabilistic characteristics does not provide the desired accuracy of calculating electrical loads and their optimization under the conditions of operation of industrial energy equipment, as the difference between calculated and actual loads reaches 200%.

Research conducted using a systems approach allows the development of methods for optimizing electrical loads by identifying clear dependencies between the operation of the electric drive and its energy indicators.

Below is a consideration of the solution to the posed problem under the most typical conditions of unit operation.

Continuous operation mode of the unit

This mode can be of two types:

a) Continuous operation mode with constant hourly productivity;

b) Continuous operation mode with varying productivity.

When units operate in modes a and b, the power consumption can be expressed by the following formula:

$$P = P_i + P_a + P_u, \quad (1)$$

where P_i is the idle power,

P_a is the power of auxiliary mechanisms,

P_u is the useful power of the unit.

In cases where the value of P fluctuates due to random factors, the average value P_{avg} is taken as the calculated load; the powers P_i and P_a can be assumed as constant quantities. An exception can be made for units whose P_i may undergo certain changes during the calculation period. An example of this can be cement tube ball mills, whose grinding bodies lose weight over time, thereby significantly reducing the idle power consumption.

Continuous operation mode of the unit with constant hourly productivity

In this mode, the consumed power P is practically unchanged provided that: $P_i = const$; $P_a = const$; $P_n = const$; $A = const$.

Under the condition $P_i = var$, and $P_a = const$, the resultant power over the calculation period changes within certain limits.

Continuous operation mode of the unit with varying productivity

In operational conditions, various disruptions in the rhythm of product feed, subject to processing, may occur, causing changes in productivity and, accordingly, consumed power. In this case, the nature of the change in consumed power can be expressed by formula (1).

Operation of the unit in a variable mode

Units may operate in several modes:

1) Alternation of maximum load with the complete shutdown of the unit,

2) Alternation of maximum load with the unit in idle mode,

3) Alternation of maximum and reduced loads.

In all modes, the average power is considered, which depends on the average productivity $P_{avg} = f(A_{avg})$.

A special consideration in the calculation of consumed power in the unit when operating in these modes is given to the startup costs of the units, which in some cases constitute a significant portion of the overall electricity consumption [7]. The magnitude of startup costs (startup and shutdown mode) has a significant impact on the energy indicators of the unit, each having its unique characteristics. The magnitude of these costs is mostly determined experimentally and should be accounted for in the process of optimizing electricity consumption modes.

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